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Controlled experiments and finite element simulations with the Swiss plate geophone bedload monitoring system: particle size identification and transport mode

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The Swiss plate geophone (SPG) system is an indirect bedload transport monitoring device that records the acoustic signals generated by bedload particle impacts, with the goal to derive the bedload flux and grain size distribution. Particle drop experiments with quartz spheres in quiescent water in a flume setting were performed to investigate the dynamic signal response of the SPG system impacted by particle-like objects varying in size and impact location. Systematic flume experiments with natural bedload particles in flowing water were conducted to study the effects of impact angle and transport mode (saltating, rolling and sliding) on the SPG signals. For each impact caused by a single particle, the number of signal impulses, the amplitude, the positive area surrounded by the signal envelope, and the centroid frequency were extracted from the raw geophone monitoring data. The finite element method (FEM) was used to construct a virtual model of the SPG system and to determine the propagation characteristics of the numerical stress wave in the material structure. The experimental and numerical results showed a qualitative and partially quantitative agreement in the changes of the signal impulses, the amplitude, and the envelope area with increasing colliding sphere size. The centroid frequencies of the SPG vibrations showed qualitatively similar dependencies with increasing particle size as some field measurements for the coarser part of the investigated range of impact sizes. The effects of variable particle impact velocities and impact locations on the geophone plate were also investigated by drop experiments and compared to FEM simulations. In addition, the signal response for different bedload transport modes and varying impact angles were explored. In summary, the FEM simulations contribute to the understanding of the signal response of the SPG system and the findings in this study may eventually result in improving the bedload grain size classification and transport mode recognition.